Electrified Liquid Jets from Nanostructured Surfaces for Phase Change Heat Transfer Enhancement

Completed Technology Project (2016 - 2020)

Project Introduction

The need exists to dissipate up to 1kW/cm2 with minimum cooling power overhead and a minimum weight. Using micro and nanostructures on hot surfaces recently emerged as a promising approach to intensify cooling. Heat transfer can be further significantly enhanced by applying an electric field to partially or fully wetted nanostructures, since the electric field reduces surface tension of most fluids and alters direction of fluid motion and film thicknesses on these structures. Heat transfer is also improved by jet impingement of the coolant on the surface, for example using the electrospray process, along with evaporation of the liquid film formed on the hot surface. In one case, heat transfer may be improved through electrowetting of the porous surface and induced electrospray of fluid through micropores. In another potential case, nano-cone structures are wetted (increasing contact area) and electrospray is induced through the application of a voltage bias, which may also improve heat transfer. Analysis of these interactions, however, can be complex as the electric field which alters behavior of the fluid (on microscopic and macroscopic scales) is itself impacted by the movement of the fluid. Research needs done to understand and model these effects to predict the improved heat transfer that can result in the aforementioned scenarios. The research team I will be working with at GA Tech has demonstrated the ability to fabricate nanostructures through advanced techniques including electron-beam direct writing, electron-beam nanolithography, and focused ion beam nano-milling, all of which have a resolution of <50 nm. The general method for research will be to vary the jet impingement velocity and liquid film coverage of the surface (which can be achieved by tuning the electric field magnitude, distance to the substrate, distance between individual nozzles, and properties of the coolant and the impingement surface), and then observe the effect via optical/electron microscope and thermal measurements (via surface integrated resistance thermometry and infrared micro-camera imaging). These observations will then be used to derive a physics model of the underlying phenomena. Once a model has been formulated, it will be validated through the fabrication of subsequent nanostructures whose heat transfer performance should be accurately described by the theoretical models. Deviations from the model will be analyzed to further correct the model and this process will be repeated until an accurate model is completed and the underlying phenomena can be fully characterized. Ultimately it should be possible to use this model to determine the structures, materials, and operating parameters which will provide the best system performance and to identify new modes of cooling system operation that could not be determined even through exploration of an excessively large parametric space. System performance for this application will be determined through observing the maximum heat flux that can be dissipated while keeping the mock processor (an array of substrate-deposited resistance heaters) below the maximum temperature that would be permitted for a processor to achieve (approximately 90 Celsius for typical silicon processors and 125-150 Celsius for silicon carbide power electronics). This research is significant for NASA due to the weight reduction that can be

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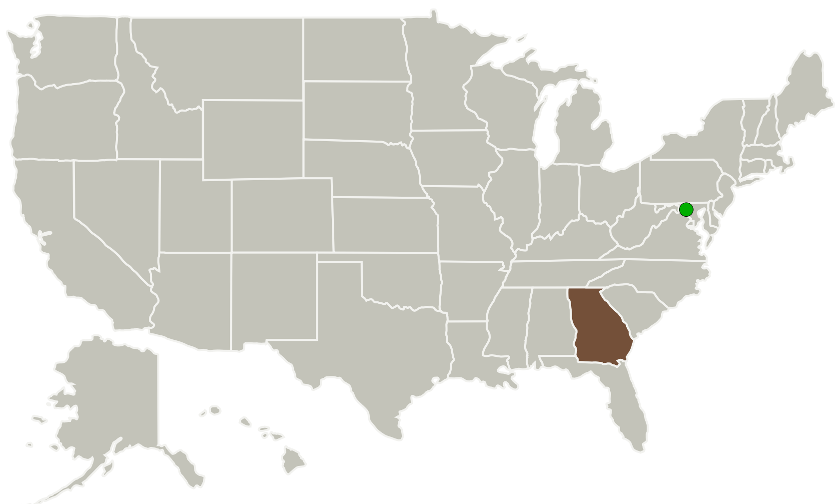
realized when compared to conventional heat sinks and even more so when compared to liquid cooling systems, and every microprocessor used could benefit from these weight savings. Interest has been expressed under TA 14.2.2.10.

Anticipated Benefits

This research is significant for NASA due to the weight reduction that can be realized when compared to conventional heat sinks and even more so when compared to liquid cooling systems, and every microprocessor used could benefit from these weight savings.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Georgia Institute of Technology-Main Campus(GA Tech)	Lead Organization	Academia	Atlanta, Georgia
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Georgia Institute of Technology-Main Campus (GA Tech)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Andrei G Fedorov

Co-Investigator:

Joel Chapman

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Primary U.S. Work Locations

Georgia

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX14 Thermal Management Systems
  └ TX14.2 Thermal Control Components and Systems
    └ TX14.2.2 Heat Transport

Target Destination

Earth